DESCRIPTION

LASER DRIVING DEVICE,

OPTICAL HEAD INCORPORATING LASER DRIVING DEVICE,

AND

OPTICAL DISK APPARATUS

TECHNICAL FIELD

【0001】

The present invention relates to a laser driving device for driving a semiconductor laser. More specifically, the present invention relates to a laser driving device for writing data on a storage medium such as an optical disk and reading data written thereon, and an apparatus having such a laser driving device.

BACKGROUND ART

【0002】

A large number of apparatuses have been developed which employ a semiconductor laser to record information on and

reproduce information from a storage medium. Among such apparatuses, optical disk apparatuses are drawing great attention as apparatuses that are capable of coping with the increase in information amounts in the recent years.

【0003】

An optical disk apparatus has an optical head, and supplies a current to a semiconductor laser which is mounted in the optical head to cause the semiconductor laser to emit light. When reproducing information, the optical disk apparatus converges weak reproduction light on the disk to read information which is recorded on the optical disk in the form of marks, pits, etc., based upon reflectance, angles of deviation, or the like. When recording or erasing information, the optical disk apparatus supplies a larger current to the semiconductor laser than when reproduction is performed, thus causing the semiconductor laser to emit light with a large light amount (high power). As a result, a physical change is caused in the material on the optical disk, whereby information is recorded in the form of marks, pits, etc., or the existing information is erased.

【0004】

FIG. **1** shows a commonly-used connection structure for driving a semiconductor laser. When supplied with a voltage (Vld) from a power source **3**, a laser driving section **2** supplies the current from the power source **3** to the semiconductor laser **1**. Based on this current, the semiconductor laser **1** emits light with a power which is in accordance with the size of the current.

【0005】

In FIG. **1**, a voltage which is necessary for the laser driving section **2** to operate is represented as an "operating voltage Vtr", whereas a voltage which is necessary for the semiconductor laser **1** to operate is represented as an "operating voltage Vop". Note that the operating voltage Vop is a voltage, between an anode and a cathode, which is necessary for causing the semiconductor laser **1** to emit light.

【0006】

In order for the semiconductor laser **1** to emit light, the respective voltages must satisfy the following formula.

【0007】

$$Vld \geqq Vop + Vtr \qquad \text{(Formula 1)}$$

【0008】

Herein, the laser operating voltage Vop varies in accordance with a current (laser driving current) which is flown in the semiconductor laser, for example.

【0009】

FIG. **2** is a graph showing the laser driving current-laser emission power characteristics **A** (Iop-P characteristics **A**) and the laser driving current-laser operating voltage characteristics **B** (Iop-Vop characteristics **B**) of a semiconductor laser. As shown by the Iop-P characteristics **A**, the emission power of a semiconductor laser varies in accordance with the laser driving current. Therefore, by controlling the value of the driving current (Iop), it is possible to cause the semiconductor laser to emit light with a desired power. On the other hand, as shown by the Iop-Vop characteristics **B**, the laser operating voltage Vop varies from Vop0 to Vop2 in accordance with the laser driving current. Therefore, the laser can adequately emit light

across the entire current range so long as the voltage of the power source which supplies power to the laser driving section **2** is:

$$Vld \geqq Vop2 + Vtr. \qquad \text{(Formula 2)}$$

【0010】

However, power will be wastefully consumed if a source voltage Vld that satisfies formula 2 is always supplied irrespective of the value of the laser driving current (or the laser operating voltage). Specifically, when the laser driving current Iop is small (e.g., Iop=Iop1 (FIG. **2**)), a laser operating voltage of Vop1 would suffice; however, a power of Iop1 × (Vop2-Vop1) will be wastefully consumed because formula 2 assumes the laser operating voltage to be Vop2.

【0011】

Regarding this problem, a technique of switching the voltage to be supplied to the laser driving section in a stepwise manner, in accordance with the operating voltage of the laser, is disclosed in Patent Document 1, for example.

【0012】

FIG. **3** shows the functional block construction of a conventional semiconductor laser driving device **300**. Based on an instruction from a user, a power setting section **306** outputs a setting instruction signal **b**. It is assumed that the setting instruction signal **b** is variable depending on the mode of operation, i.e., recording of information or reproduction of information. Based on an output value (i.e. an instruction value) from a laser power control section **307**, a laser driving section **302** causes a driving current to flow through a semiconductor laser **301**.

【0013】

When the semiconductor laser **301** emits laser light, a portion thereof enters a photodetector **303**. The photodetector **303** outputs a current of a size which is in accordance with the power of the received light, that is, the emission power of the semiconductor laser **301**. A current-voltage converter **304** converts the output current from the photodetector **303** into a voltage signal. Note that the photodetector **303** and the current-voltage converter **304** together compose an emission power detecting section **305**.

From the emission power detecting section **305**, a power detection signal **a** which represents the emission power of the semiconductor laser **301** is output.

【0014】

The laser power control section **307** controls the instruction value for the laser driving section **302** so that the power detection signal **a** becomes equal to a reference voltage signal **b**. As a result, the current amount of the laser driving current that is supplied from the laser driving section **302** to the semiconductor laser **301** can be controlled, whereby the emission power of the semiconductor laser **301** is controlled so as to be appropriate for both reproduction of information and recording of information.

【0015】

On the other hand, an operating voltage detecting section **308** detects the operating voltage value Vop of the semiconductor laser **301**, and sends it to a voltage selection section **309**. In accordance with the voltage value of the laser operating voltage Vop which has been detected in the operating voltage detecting section **308**, the voltage

selection section **309** selects a voltage Vc to be supplied to the laser driving section **302,** and sends it to a voltage control section **310.** The voltage control section **310,** which is composed of a DC/DC converter, for example, supplies the selected voltage Vc to the laser driving section **302.**

【0016】

Now, with reference to FIG. **4,** an example method by which the voltage Vc is selected in the voltage selection section **309** will be described. FIG. **4** shows a determination procedure in a conventional voltage selecting process.

【0017】

At step **S41,** the voltage selection section **309** compares the current operating voltage Vop against the first voltage Vop1. If the result of the comparison indicates that the operating voltage Vop is equal to or greater than the predetermined voltage Vop1, control proceeds to step **S42;** if the operating voltage Vop is equal to or greater than the predetermined voltage Vop1, control proceeds to step **43.**

【0018】

At step **S42,** the voltage selection section **309** selects a

voltage Vc=Vop2+Vtr, which corresponds to the maximum estimated value Vop2 of the operating voltage Vop. On the other hand, at step **S43**, the voltage selection section **309** selects Vc=Vop1+Vtr. As a result, unnecessary power consumption can be reduced.

[Patent Document 1] Japanese Laid-Open Patent Publication No. 2000-244052

DISCLOSURE OF INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

【0019】

However, the conventional construction has a problem in that it requires dedicated component elements for detecting the operating voltage of the semiconductor laser (e.g., the operating voltage detecting section **308** in FIG. **3**), thus leading to an increased cost. Moreover, a space for installing such component elements will be needed on the optical head having the semiconductor laser mounted thereon, which would become a hindrance in downsizing.

【0020】

Furthermore, since the voltage Vc to be supplied to the laser driving section is switched in a stepwise manner, it has been difficult to supply an optimum voltage Vc at all times. The reason is that, if a conceivable method for switching the voltage Vc were to be adopted, i.e., dividing a predetermined voltage in such a manner that the ratio of voltage division is variable, a number of resistors corresponding to the number of steps in the voltage Vc would be required; in practice, switching in only a few steps can be realized.

MEANS FOR SOLVING THE PROBLEMS

【0021】

An object of the present invention is to provide a semiconductor laser driving device which makes enables to reduce unnecessary power consumption without requiring dedicated component elements.

【0022】

A laser driving device according to the present invention includes: a laser driving section for supplying a

driving current for causing a laser to emit light; a temperature detecting section for detecting a temperature of the laser; and a voltage control section for supplying a source voltage to the laser driving section while changing a voltage value of the source voltage in accordance with the temperature detected by the temperature detecting section.

【0023】

The laser driving device may further include a power control section for causing the laser to emit light with a predetermined emission power by controlling an instruction value for the laser driving section so as to adjust the driving current which is supplied from the laser driving section.

【0024】

The laser driving device may further include a setting section for instructing a setting of a reference voltage in accordance with an amount of light to be emitted by the laser.

【0025】

The laser driving device further includes an emission

power detecting section for detecting a value which is in accordance with the emission power of the laser and outputting a signal corresponding to the value. The power control section may control the instruction value to the laser driving section based on a voltage of the signal which is output from the emission power detecting section and the reference voltage, in such a manner that the voltage of the signal equals the reference voltage.

【0026】

Characteristics between an operating voltage necessary for the laser to operate and the driving current differ depending on temperature. The voltage control section may determine the voltage value of the source voltage based on the driving current and the characteristics.

【0027】

The operating voltage may increase as the temperature decreases; and the voltage control section may supply a higher source voltage as the temperature decreases.

【0028】

The laser driving section may output a driving current

for causing a laser whose wavelength is within a range from 400 nm to 430 nm to emit light.

【0029】

An optical head according to the present invention is used for performing a data write and/or read operation with respect to an information recording layer of a storage medium. The optical head includes: a laser; a laser driving device for supplying a driving current for causing the laser to emit light; an objective lens for converging light from the laser onto the information recording layer; and a light-receiving section for receiving light reflected from the information recording layer and for outputting a signal which is in accordance with the amount of light. The laser driving device includes: a temperature detecting section for detecting a temperature of the laser; and a voltage control section for supplying a source voltage to the laser driving section while changing a voltage value of the source voltage in accordance with the temperature detected by the temperature detecting section.

【0030】

An optical disk apparatus according to the present invention is used for performing a data write and/or read operation with respect to an information recording layer of an optical disk. The optical disk apparatus includes: an optical head for radiating light toward the optical disk, and generating and outputting a servo signal based on light which is reflected from the information recording layer; a control signal generating section for generating a control signal for controlling the position of a focal point of the light based on the servo signal which is output from the optical head; and a driving circuit for generating a driving signal based on the control signal. The optical head includes: a laser; a laser driving device for supplying a driving current for causing the laser to emit light; an objective lens for converging light from the laser onto the information recording layer; an actuator for adjusting a position of the objective lens based on the driving signal; and a light-receiving section for receiving light reflected from the information recording layer and for outputting a signal which is in accordance with the amount of light. Furthermore, the

laser driving device includes: a temperature detecting section for detecting a temperature of the laser; and a voltage control section for supplying a source voltage to the laser driving section while changing a voltage value of the source voltage in accordance with the temperature detected by the temperature detecting section.

【0031】

A laser driving method according to the present invention includes the steps of: supplying a driving current for causing a laser to emit light; detecting a temperature of the laser; and supplying a source voltage when executing the step of supplying the driving current, a voltage value of the source voltage being changed in accordance with the detected temperature.

EFFECTS OF THE INVENTION

【0032】

According to the present invention, there is provided a driving device for a semiconductor laser which makes it possible to reduce power consumption without requiring any

new component elements. An appliance having the driving device according to the present invention will make energy savings possible, and further suppress temperature increases. As such an appliance, for example, an optical disk apparatus which performs a data write and read operation with respect to an optical disk by using a blue-violet laser light would be suitable. In particular, a mobile-type appliance (e.g., a mobile optical disk apparatus) which is under severe requirements concerning temperature increase suppression and power savings of the appliance would be suitable.

BRIEF DESCRIPTION OF DRAWINGS

【0033】

[FIG. **1**] A diagram showing a commonly-used connection structure for driving a semiconductor laser.

[FIG. **2**] A graph showing the laser driving current-laser emission power characteristics **A** (Iop-P characteristics **A**) and the laser driving current-laser operating voltage characteristics **B** (Iop-Vop characteristics **B**) of a semiconductor laser.

[FIG. **3**] A diagram showing the functional block construction of a conventional semiconductor laser driving device **300**.

[FIG. **4**] A diagram showing a determination procedure in a conventional voltage selecting process.

[FIG. **5**] A diagram showing the functional block construction of an optical disk apparatus **50** according to an embodiment of the present invention.

[FIG. **6**] A diagram showing the functional block construction of a laser driving device **10** according to an embodiment of the present invention.

[FIG. **7**] A diagram showing the functional block construction of a laser power control section **12**.

[FIG. **8**] A graph showing the laser driving current-laser operating voltage characteristics (Iop-Vop characteristics) of a blue-violet semiconductor laser with respect to temperature.

[FIG. **9**] A diagram showing the circuit construction of a temperature detecting section **21** and a voltage control section **22**.

[FIG. **10**] **(a)** a graph showing the temperature characteristics of a resistance value **Rth** of a thermistor **21;** and **(b)** a graph showing the temperature characteristics of an output voltage of the voltage control section **22.**

[FIG. **11**] A diagram showing the construction of a laser driving section **20.**

[FIG. **12**] A flowchart showing a procedure of processing by the optical disk apparatus **50.**

DESCRIPTION OF THE REFERENCE NUMERALS

【0034】

1 semiconductor laser

7 light-receiving section

8 current-voltage converter

10 laser driving device

11 power setting section

12 laser power control section

20 laser driving section

21 temperature detecting section

22 voltage control section

24 emission power detecting section

50 optical disk apparatus

52 optical head

54 control signal generating section

56 driving circuit

58 reproduction processing section

60 optical disk

BEST MODE FOR CARRYING OUT THE INVENTION

【0035】

Hereinafter, with reference to the accompanying figures, an embodiment of the present invention will be described.

【0036】

FIG. **5** shows the functional block construction of an optical disk apparatus **50** according to the present embodiment. The optical disk apparatus **50** is capable of performing data write and/or read operation for an optical disk **60**. For example, the optical disk apparatus **50** is a mobile-type video reproduction appliance for reproducing a movie which is recorded on an optical disk, or a camcorder

for recording video and audio onto an optical disk.

【0037】

As the optical disk **60**, a BD (Blu-ray Disc) is contemplated, for example. Although an optical disk will be illustrated in the present specification, any optical information storage medium, e.g., a card, which is capable of optical data read and write is also applicable, for example.

【0038】

The optical disk apparatus **50** includes an optical head **52**, a control signal generating section **54**, a driving circuit **56**, and a reproduction processing section **58**.

【0039】

The optical head **52** has an optical system which radiates laser light toward the optical disk **60**, and receives reflected light therefrom. The optical head **52** performs control for changing the focal point of light along a radial direction and a normal direction of the optical disk **60** so as to be accurately positioned on a track on the optical disk **60**. While this control is being performed, a data write and/or read operation is performed for the optical disk **60**.

The construction of the optical head **52** will be specifically described later. Although FIG. **5** illustrates the optical disk **60** for convenience of description, it must be noted that the optical disk **60** is not a component element of the optical disk apparatus **50**. The optical disk **60** is mounted to the optical disk apparatus **50**, and taken out from the optical disk apparatus **50**.

【0040】

Based on servo signals which are output from the optical head **52**, e.g., a tracking error signal (TE signal) and a focus error signal (FE signal), the control signal generating section **54** generates a control signal for controlling the relative positioning between a light spot of laser light and a track on the optical disk **60** with respect to the radial direction and the normal direction. The control signal which is output from the control signal generating section **54** is supplied to the driving circuit **56**. Based on the received control signal, the driving circuit **56** generates a driving signal, and applies it to an actuator **5** (described below) or a transport stage (not shown) of the optical head **52**. They

respectively cause the objective lens **4** and the entire optical head **52** to be moved along the radial direction and normal direction of the optical disk **60**, thus adjusting the relative position between the light spot of laser light and a track on the optical disk **60**. While servo control such as focusing control and tracking control is being stably performed, the reproduction processing section **58** performs a predetermined reproduction process with respect to the reflected light from the optical disk **60**, and outputs video and audio signals for reproduction.

【0041】

Next, the construction of the optical head **52** will be described. The optical head **52** includes a semiconductor laser **1**, a beam splitter **2**, a collimating lens **3**, an objective lens **4**, an actuator **5**, a diffraction element **6**, light-receiving sections **7** and **19**, a current-voltage converter **8**, a signal processing section **9**, a laser driving device **10**, and a converging lens **18**.

【0042】

The semiconductor laser **1** is a light source which

outputs blue-violet laser light having a wavelength of 405 nm, for example. This wavelength value does not need to be exact, but may be in the range from 400 nm to 415 nm, or in the range from 400 nm to 430 nm, for example. It is preferably in the range of 405±5 nm.

【0043】

The beam splitter **2** transmits a portion of the light, while reflecting the remainder. The collimating lens **3** collimates the light from the semiconductor laser **1** into parallel light. The objective lens **4** converges the laser light which has been radiated from the semiconductor laser **1**, so as to form a focal point at a predetermined distance. The diffraction element **6** receives light which is reflected from the optical disk **60**, and diffracts a portion of the light through a predetermined diffraction region.

【0044】

The light-receiving section **7** has a plurality of light-receiving regions, each light-receiving region outputting a photocurrent of a size which is in accordance with the light amount of the received light. Based on the photocurrent, the

signal processing section **9** generates a tracking error signal (TE signal), a focus error signal (FE signal), a reproduction signal, and the like. The TE signal represents an offset between the light spot position of laser light and a desired track on the optical disk **60** along the radial direction of the optical disk **60**. The FE signal represents an offset between the light spot position of laser light and an information recording layer of the optical disk **60** along the normal direction of the optical disk **60**.

【0045】

A portion of the light having been radiated from the semiconductor laser **1** enters the converging lens **18**, which converges a light beam at the light-receiving section **19**. The light-receiving section **19** outputs a photocurrent of a size which is in accordance with the received light amount. The current-voltage converter **8** converts the photocurrent output from the light-receiving section **19** into a voltage, and outputs it as a power detection signal **a**.

【0046】

Next, the process which is performed in the optical head

52 will be described, along the light path. Most of the light which is radiated from the semiconductor laser **1** is transmitted through the beam splitter **2**, collimated by the collimating lens **3** into parallel light and then enters the objective lens **4**, and is converged by the objective lens **4** onto the information recording layer of the optical disk **60**.

【0047】

The light which is reflected from the optical disk **60** again passes through the objective lens **4** and the collimating lens **3** to enter the beam splitter **2**. The light which is reflected from the beam splitter **2** enters the diffraction element **6**, where a plurality of rays of light are obtained through diffraction. Each light-receiving region of the light-receiving section **7** receives the light having been split by the diffraction element **6**. Each light-receiving region outputs a photocurrent which is in accordance with the amount of received light.

【0048】

The photocurrent which is output from the light-receiving section **7** is sent to the signal processing section

9. The signal processing section **9** generates a TE signal and an FE signal based on the photocurrent. Based on the TE signal and FE signal, a control signal is generated in the control signal generating section **54,** with which tracking control and focusing control are realized. Since it is well known as to how the FE signal and TE signal are generated and how the positions of the objective lens **4** and the optical head **52** are adjusted based on these signals, the descriptions thereof are omitted here.

【0049】

On the other hand, a portion of the light which has been radiated from the semiconductor laser **1** is reflected by the beam splitter **2,** enters the converging lens **18,** and is converged by the converging lens **18** onto the light-receiving section **19.** A photocurrent which is output from the light-receiving section **19** is sent to the current-voltage converter **8.** The photocurrent is converted by the current-voltage converter **8** into a voltage, and sent to the laser driving device **10.** Based on this light amount, the laser driving device **10** controls the current amount flowing through the

semiconductor laser **1** and its voltage value.

【0050】

Next, with reference to FIG. **6**, the detailed construction of the laser driving device **10** will be described. FIG. **6** shows the functional block construction of the laser driving device **10** according to the present embodiment. In FIG. **6**, the light-receiving section **19** and the current-voltage converter **8** are collectively shown as an emission power detecting section **24**.

【0051】

The laser driving device **10** includes a power setting section **11**, a laser power control section **12**, a laser driving section **20**, a temperature detecting section **21**, and a voltage control section **22**.

【0052】

Among these component elements, the laser driving section **20** allows a driving current to flow through the semiconductor laser **1** based on a value (instruction value) which is output from the laser power control section **12**. Therefore, those component elements which are related to the

laser power control section **12** will be described, followed by descriptions of those component elements which are related to the voltage control section **22**.

【0053】

First, the laser power control section **12** receives a setting instruction signal **b** from the power setting section **11**. The setting instruction signal **b** is output based on a user instruction or the like. For example, in the case where the optical disk apparatus **50** is an appliance which is capable of both recording and reproduction of information, the setting instruction signal **b** contains an instruction (reference voltage) which sets a power that corresponds to an operation (recording operation or reproduction operation) which is selected by the user. In the case where the optical disk apparatus **50** is a read-only appliance, or where playback is to be performed in a camcorder, the setting instruction signal **b** contains an instruction (reference voltage) which sets a power that corresponds to a playback operation (normal playback operation, fast playback operation, etc.) which is selected by the user.

【0054】

Now, with reference to FIG. **7**, the specific construction of the power setting section **11** and the laser power control section **12** will be described. FIG. **7** shows the functional block construction of the power setting section **11** and the laser power control section **12**. The power setting section **11** includes a first reference voltage source **121a** and a second reference voltage source **121b**, and a switch **122**. The first reference voltage source **121a** and the second reference voltage source **121b** are voltage sources which are capable of providing reference voltages for obtaining emission powers that are necessary for recording and reproduction, respectively, of information for the optical disk **60**. The switch **122** connects one of the voltage sources to the differential amplifier **123** depending on recording or reproduction.

【0055】

The laser power control section **12** includes a differential amplifier **123**. The differential amplifier **123** is connected to the current-voltage converter **8**, and receives

the power detection signal **a**, which is represented as a voltage value. The differential amplifier **123** is connected to one of the first reference voltage source **121a** and the second reference voltage source **121b** to receive a reference voltage which serves as an operation reference.

【0056】

The differential amplifier **123** receives a voltage corresponding to the power detection signal **a** and a reference voltage from a voltage source in the power setting section **11** corresponding to the setting instruction signal **b**. After a difference therebetween is calculated and amplified, it is output as a voltage signal **Vk** and sent to the laser driving section **20**. This voltage signal **Vk** is utilized as a voltage for the laser driving section **20** to adjust the driving current to flow through the semiconductor laser **1**. In other words, the laser power control section **12** can be regarded as controlling the current amount (current value) of the driving current for causing the semiconductor laser **1** to emit light. Note that, while the semiconductor laser **1** is emitting light, the power detection signal **a** is always sent to the laser

power control section **12** and a power control based on the power detection signal **a** is performed, and the laser power control section **12** operates in such a manner that the power detection signal **a** equals the reference voltage signal. As a result, the current amount of the driving current which is supplied from the laser driving section **20** to the semiconductor laser **1** can be controlled (adjusted), whereby the emission power of the semiconductor laser **1** is appropriately controlled to a level which is necessary for the operation. Note that the construction of the laser power control section **12** shown in FIG. **7** is exemplary, and there is no limitation to this particular construction.

【0057】

Next, referring back to FIG. **6**, the temperature detecting section **21** and the voltage control section **22** will be described. The temperature detecting section **21** detects a temperature in the surroundings of the semiconductor laser **1**, and supplies information which is in accordance with the detected temperature to the voltage control section **22**. As will be described later, the temperature detecting section **21**

is a thermistor in the present embodiment. Since a thermistor has a resistance value which changes with temperature, the change in its resistance value serves as the information to be provided to the voltage control section **22**. Note that FIG. **6** illustrates the temperature detecting section **21** as being distant from the semiconductor laser **1**, only for convenience of illustration. The temperature detecting section **21** is disposed near the package of the semiconductor laser **1**, for example.

【0058】

As will be described below, the aforementioned temperature detecting section **21** plays a prominent role in driving the semiconductor laser **1**. However, the temperature detecting section **21** does not need to be a dedicated component element for implementing the present invention, because, in a general apparatus which employs a semiconductor laser (e.g., an optical head and an optical disk apparatus incorporating such an optical head), an element for temperature detection is already mounted for other purposes as will be exemplified below. Therefore, it can be said that

the temperature detecting section **21** of the present embodiment makes use of an already-existing component element in the optical head. Therefore, the temperature detecting section **21** does not need to be provided in the laser driving device **10**. In other words, the laser driving device **10** does not need to include the temperature detecting section **21** as its own component element. It suffices if the temperature detecting section **21** is provided within the optical head **52**.

【0059】

Examples where a temperature detection element may be mounted on an optical head are as follows. Since a semiconductor laser is liable to destruction or deterioration during a high-temperature operation, it is necessary to stop a reproduction or recording operation in times of a high temperature. Therefore, a temperature detection element is provided so as to be used for detecting the temperature in the surroundings of the semiconductor laser and ensuring protection thereof.

【0060】

Moreover, in an optical disk apparatus, the emission

power which is optimum for reproduction or recording of information and the optimum recording strategy for laser light generally vary depending on temperature. For this reason, a temperature detection element is provided so as to be used for correcting the emission power or recording strategy depending on the detected temperature (for example, Japanese Laid-Open Patent Publication No. 7-182721 and Japanese Laid-Open Patent Publication No. 2001-297437).

【0061】

The voltage control section **22** supplies a source voltage **Vc** to the laser driving section **2**. The source voltage **Vc** is a voltage which is necessary for driving the laser driving section **20** and the semiconductor laser **1**. More specifically, in accordance with the temperature which is detected by the temperature detecting section **21**, the voltage control section **22** adaptively changes the voltage **Vc** to be supplied to the laser driving section **2**. The voltage control section **22** controls the voltage **Vc**, at a relatively low temperature, so as to be increased, and controls the voltage **Vc**, at a relatively high temperature, so as to be decreased.

【0062】

Now, in order to describe the operation principles of the temperature detecting section **21** and the voltage control section **22**, the temperature dependence of an operating voltage of a commonly-used laser light source which includes the semiconductor laser **1** will be described. It is known that, in a blue-violet laser having a wavelength of 400 to 430 nm, the laser operating voltage increases as the temperature becomes lower (e.g., "Optronics Magazine", 2003 May issue, The Optronics Co., Ltd., P121). FIG. **8** is a graph showing the laser driving current-laser operating voltage characteristics (Iop-Vop characteristics) of a blue-violet semiconductor laser with respect to temperature. The operating voltage of the semiconductor laser depends largely on temperature.

【0063】

Specifically, when the temperature within the package of the semiconductor laser is relatively high (e.g., about 40°C), the laser operating voltage (Vop) stays at a relatively low value (VopH) or below. On the other hand,

when the temperature within the package of the semiconductor laser is relatively low (e.g., about 20°C), the laser operating voltage becomes drastically high, with its value becoming greater than the aforementioned value of VopH. As shown by the laser driving current-laser emission power characteristics **A** (Iop-P characteristics **A**) in FIG. **2**, when an emission power (P) of the semiconductor laser **1** is identified, a driving current (Iop) which gives that power is identified. However, the value of the operating voltage (Vop) for obtaining that driving current (Iop) will vary depending on the temperature of the semiconductor laser **1**.

【0064】

In the present embodiment, by taking these facts into consideration, the voltage control section **22** operates in accordance with the temperature which is detected in the temperature detecting section **21**, as follows. At a high temperature, the voltage control section **22** controls the output voltage **Vc** so that a voltage **Vc** obtained as

Vc = VopH + Vtr (Formula 3)

is supplied to the laser driving section **2**. In formula 3,

"Vtr" is a voltage which is necessary for the laser driving section **2** to operate. Similarly, at a low temperature, the voltage control section **22** controls the output voltage **Vc** so that a voltage **Vc** obtained as

$$Vc = VopL + Vtr \qquad \text{(Formula 4)}$$

is supply to the laser driving section **2**. Specific examples of these voltage values are: VopH=4.5V, VopL=6.5V, Vtr=2V.

【0065】

From the standpoint of ensuring operation regardless of a low temperature or a high temperature, **Vc** as shown by formula 4 may always be supplied. However, by supplying a voltage **Vc** as obtained by formula 3 in times of a high temperature, a power reduction by (VopL-VopH) × Iop is possible.

【0066】

In the present specification, the value of the output voltage **Vc** of the voltage control section **22** is controlled between two steps, i.e., an operating voltage VopH shown by formula 3 and an operating voltage VopL shown by formula 4. However, "two steps" is only exemplary. A greater number of

steps may be used, or the value of the output voltage **Vc** may be controlled in a stepless manner in accordance with temperature. The latter control can be realized by, for example, previously sampling the operating voltage of the semiconductor laser **1** at each temperature and with respect to each size of driving current (Iop) that is needed, and store them in a table or the like. Once the size of the driving current (Iop) and the temperature of the semiconductor laser **1** at that time are identified, an operating voltage (Vop) can be obtained by referring to that table. By substituting this value in VopL in formula 3 (or VopH in formula 4), the voltage **Vc** at that time is identified.

【0067】

As mentioned earlier, the temperature detecting section **21** does not need to be provided as a dedicated element on the optical head **52**. Therefore, power savings can be realized without requiring any new component elements.

【0068】

Although the temperature mentioned above is supposed to be a temperature within the package of the semiconductor

laser, this temperature may vary depending on the temperature of the surrounding environment in which the package is installed. In the case where the package is provided within a drive device of an optical disk apparatus or the like, the temperature of the package would be equivalent to the room temperature drive in an environment where the device is not operating, e.g., immediately after activation of the drive device. However, once the drive device is activated and a predetermined period has elapsed, the temperature of the package will be higher than the room temperature by about 10 to 20°C. Therefore, it is well possible that a difference of about 20°C may emerge between the intra-package temperature immediately after activation and the intra-package temperature after the lapse of a certain period or more.

【0069】

Next, constructions for realizing the above-described operation will be described. FIG. **9** shows the circuit construction of the temperature detecting section **21** and the voltage control section **22**. In FIG. **9,** what has been referred to as the temperature detecting section **21** is shown

as a "thermistor **21**".

【0070】

On the other hand, the voltage control section **22** includes a power source **31** and resistors **32** and **33**. The resistor **32** is connected in parallel to the thermistor **21**. One end of each of the resistor **32** and the thermistor **21** is connected to one end of the resistor **33**. From within this connection path, the voltage **Vc** of the voltage control section **22** is taken out for output. The other ends of the resistor **32** and the thermistor **21** are connected to ground. On the other hand, the power source **31** (voltage value **Vcc**) is connected to the other end of the resistor **33**.

【0071】

FIG. **10(a)** shows the temperature characteristics of a resistance value **Rth** of the thermistor **21**. The thermistor **21** has its resistance value **Rth** increased as the temperature decreases, and has its resistance value **Rth** decreased as the temperature increases.

【0072】

On the other hand, FIG. **10(b)** shows the temperature

characteristics of an output voltage of the voltage control section **22**. When the resistance value of the resistor **33** is represented as **R33**, and so on, and the size of the current flowing through the resistor **33** is represented as **I**, the output voltage **Vc** of the voltage control section **22** is obtained as:

$$Vc=(R32//Rtho)/[(R32//Rtho)+R33]\cdot I. \quad \text{(Formula 5)}$$

From FIG. **10(b)**, it is understood that the output voltage **Vc** increases as the temperature decreases, and the output voltage **Vc** decreases as the temperature increases.

【0073】

Next, a specific construction of the laser driving section **20** shown in FIG. **6** will be described. FIG. **11** shows the construction of the laser driving section **20**. The laser driving section **20** can be implemented as a transistor. A collector terminal of the transistor **20** is connected to the voltage control section **22**, whose output voltage **Vc** is applied to the collector terminal. A base terminal of the transistor **20** is connected to the laser power control section **12**, whose output voltage **Vk** is applied to the base terminal.

An emitter terminal of the transistor **20** is connected to an anode terminal of the semiconductor laser **1**. A current **Iop** which flows through the semiconductor laser **1** from the base terminal and via the emitter terminal is obtained as:

Iop=(Vk-VBE)/z. (Formula 6)

Note that "VBE" is a voltage between the base and the emitter, whereas z is an impedance of the laser. According to formula 6, it is understood that the current **Iop** is controlled by the output voltage **Vk** of the laser power control section **12**, and is not controlled by the output voltage **Vc** of the voltage control section **22**.

【0074】

Note that, as a technique for improving the recording and/or reproduction quality, it might be conceivable to detect the ambient temperature of the semiconductor laser **1** and change the voltage **Vk** in the power setting section **11** and the laser power control section **12**. This technique would be effective for the adjustment of the voltage **Vk** which is applied to the base terminal of the laser driving section **20** as well as the driving current which is defined according to

this voltage. On the other hand, the voltage **Vc** is applied to the collector terminal of the laser driving section **20**, and therefore is independent of the aforementioned voltage **Vk**. Therefore, it still holds true that adjusting the voltage **Vc** to its lowest limit that permits operation is advantageous in terms of power consumption. Note that the laser driving section **20** is not limited to a transistor, but may be any component element that is capable of controlling the current to be supplied to the semiconductor laser **1** in accordance with the output value of the laser power control section **20**.

【0075】

Next, with reference to FIG. **12**, the processing by the optical disk apparatus **50** operating based on the above-described principle will be described. FIG. **12** shows a procedure of processing by the optical disk apparatus **50**.

【0076】

First, at the beginning of the operation of the optical disk apparatus **50** or the like, at step **S121**, the power setting section **11** receives an instruction of a playback mode

from the user, e.g., a normal playback mode, a fast playback mode, or the like. At the next step **S122**, in accordance with this playback mode, the power setting section **11** determines a driving current to be supplied to the semiconductor laser, and outputs a setting instruction for obtaining that driving current. At step **S123**, the laser power control section **12** outputs a voltage **Vk** for causing the driving current, based on the setting instruction signal **b**.

【0077】

On the other hand, the temperature detecting section **21** detects the ambient temperature of the semiconductor laser **1** at step **S124**, and then at step **S125**, the voltage control section **22** outputs a voltage **Vc** which is in accordance with the ambient temperature. This voltage is a necessary and sufficient voltage for the semiconductor laser **1** to emit light, and is not to be applied in excess. At step **S126**, the laser driving section **20** allows a laser driving current which is determined based on the voltage **Vk** to flow through the semiconductor laser **1**, whereby the semiconductor laser **1** emits light.

【0078】

At step **S127**, it is determined by the laser driving device **10** as to whether a predetermined period has elapsed or not. If the predetermined period has elapsed, control returns to step **S124** to detect the ambient temperature of the semiconductor laser **1**. If the predetermined period has not elapsed, control proceeds to step **S128**.

【0079】

The reason why this step **S127** is provided is in order to perform a more flexible laser driving control. The "predetermined period" refers to a timing with which temperature is detected by the temperature detecting section **21**, and does not need to be a fixed value. For example, within five minutes from the beginning of the operation of the optical disk apparatus **50**, the "predetermined period" may be set at every one minute, whereas after five minutes from the beginning of operation, the "predetermined period" may be set at every five minutes. Immediately after the beginning of operation, the temperature of the semiconductor laser **1** is detected relatively frequently because the temperature begins

to increase. On the other hand, after about five minutes since the beginning of operation, the temperature change is believed to substantially converge; hence, the temperature of the semiconductor laser **1** may be detected with a relatively low frequency thereafter.

【0080】

At step **S128**, it is determined by the laser driving device **10** as to whether reproduction is to be ended or not. If reproduction is to be continued, control returns to step **S126**, and the laser driving section **20** continues to allow a driving current to flow through the semiconductor laser **1**. On the other hand, if reproduction is to be ended, the driving current is cut off so that the semiconductor laser **1** stops emitting light, and the process ends. Note that the determination at step **S128** can be made based on, for example, whether or not an instruction to stop power supplying, etc., is given to the power setting section **11**.

【0081】

Through the above processing procedure, the laser driving device **10** is able to make a necessary and sufficient

use of a voltage which is necessary for driving the semiconductor laser **1**. Therefore, at the optical head **52** having the laser driving device **10**, or at the optical disk apparatus **50** in which the optical head **52** is mounted, a very effective power saving function can be provided. This power saving function is suitably applied to mobile-type optical disk apparatuses or the like, which are especially restricted in terms of available power.

【0082】

With the above-described construction, since a temperature sensor or the like that is commonly mounted in an optical head is utilized as the temperature detecting section **21**, it is possible to realize both laser emission at a low temperature and power savings at a high temperature, without requiring any new component elements.

【0083】

Note that the construction according to the present embodiment where the output voltage **Vc** of the voltage control section **22** is controlled by using the temperature detecting section **21** is especially effective in a laser driving device

which employs a blue-violet laser. The reason is that, firstly, fluctuations in the laser operating voltage of a blue-violet laser will receive very large influences of temperature as shown in FIG. **8**, and therefore a significant effect on power savings can be obtained by controlling the voltage **Vc** so as to correspond to the temperature-induced changes in the laser operating voltage. Secondly, a blue-violet laser requires a greater band gap for laser emission, and hence a higher laser operating voltage, than does a red laser or the like. Therefore, a blue-violet laser is likely to have an increased power consumption over that of a red laser, and thus the requirements concerning power savings and temperature increases of the appliance (especially at a high temperature) are even greater than those for a red laser.

【0084】

In FIG. **6**, the power setting section **11** and the laser power control section **12** are illustrated as being provided within the laser driving device **10**. However, they may be provided external to the laser driving device **10**. For example, they may be provided within the optical head **52** but

externally to the laser driving device **10**, or provided within the optical disk apparatus **50** but externally to the optical head **52**.

【0085】

Although the present embodiment illustrates an example where the temperature detecting section **21** and the voltage control section **22** are constructed by combining the thermistor **31** and the resistors **32** and **33**, these are no limitations. An IC chip may be used as the thermistor **21**, and a programmable power source may be used as a voltage control section.

【0086】

Although the present embodiment illustrates an example where the cathode terminal of the semiconductor laser is grounded, it will be appreciated that similar effects can also be obtained in the case where the anode terminal is connected to the power source.

INDUSTRIAL APPLICABILITY

【0087】

According to the present invention, provided is a driving device for a semiconductor laser which enables to reduce power consumption without requiring any new component elements. An appliance having the driving device according to the present invention will make energy savings possible, and further suppress temperature increases. As such an appliance, for example, an optical disk apparatus which performs data write and read operation with respect to an optical disk by using a blue-violet laser light would be suitable. In particular, a mobile-type appliance (e.g., a mobile optical disk apparatus) which is under severe requirements concerning temperature increase suppression and power savings of the appliance would be suitable.